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NON CHEMICAL WATER TREATMENT PROCESS FOR TDS REDUCTION IN COOLING TOWER – SPECIFIC STUDY ON ELECTRICAL CONDUCTIVITY AND TURBIDITY

K. NAVEENA LATHA[1], P. RAM REDDY[2] & D. V. RAVI SHANKAR[3]

[1]*Faculty, Department of Mechanical Engineering, TKR College of Engineering and Technology, Telangana, India*

[2]*Professor, Department of Mechanical Engineering, Former Jawaharlal Nehru Technological University, Hyderabad, India*

[3]*Professor, Principal, Department of Mechanical Engineering, TKR College of Engineering and Technology, Telangana, India*

ABSTRACT

Water is an important natural resource which is the key essential for life and livelihood. While the agricultural sector consumes a major portion of the available water resources, the growing urbanization demands more water resources for industrial and domestic use. The availability of fresh water for industrial utility purposes is the growing challenge in the recent past [1].

With the ongoing water scarcity challenges globally, it has become inevitable for industries to look alternative methods to replenish and reuse water [2]. The chemical and Non chemical methods of water treatment are gaining importance for effective water reuse in the industrial and domestic sector. The chemical water treatment methods are effective but at the same time are expensive in utility and maintenance. The non chemical water treatment methods such as filtration, membrane activation, ultrasonic treatment, magnetic separation and mechanical separation are commonly used in the industrial sector.

This research investigates the pressure drop chamber system of non chemical water treatment which is unique and effective. The pressure drop created in a closed chamber enhances the precipitate formation which results in the reduction of the Total Dissolved Salts (TDS), hardness, pH and many other associated parameters. The effect of the Pressure drop chamber working parameters on the electrical conductivity and turbidity of water is studied. The differential inlet supply air pressure is tested for increasing settling time of 30, 60, 90, 120 and 150 minutes for a pressure drop chamber length of 300 mm, Nozzle inlet diameter of 35 mm, exit diameter of 16 m and nozzle length of 50 mm. The electrical conductivity and turbidity decreases with the decreases in TDS over increasing settling time [12]. A non linear but directly proportional correlation exists between the TDS and the Electrical conductivity and turbidity.

***KEYWORDS:** Tangential Water Flow Through Nozzle, Cavitation Chamber, TDS, Hardness, Convergent Nozzles, Electrical Conductivity, Turbidity, Calcium / Magnesium & Sulphates*

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Original Article

INTRODUCTION

Over View of a Cooling Tower

Cooling towers are most commonly used heat exchanging devices in the industrial sector. Cooling Systems dissipate heat from a heat source to a heat sink. Water absorbs heat from a "hot process" mainly industrial processes and then releases heat in the cooling tower thus causing the effect of "Cooling". The cooling towers reject a large amount of heat from the system by a water loop. The usage of cooling towers is extensive with utility ranging from small industrial facilities to large refineries, power plants, chemical industries etc.[3]

In the recent times, various researched have worked on the performance of Cooling tower taking into consideration few parameters like WBT, Entropy, Temperature of Water. The effect of such parameters was on the drift elimination and the fill area. The purpose is to increase the heat transfer rate of water with direct contact of air.

Hydrodynamic Cavitation Principle

Cavitation is formation of low pressure area within the fluid which results in bubble formation. When such bubbles are subject to high pressure, the cavitation collapse occurs which is familiar as very fast condensation.

Cavitation is typically induced by fast moving liquid stream (convergent nozzles), ultrasonic waves, focussed laser beam or electric spark. The most preferred liquid treatment by cavitation in large bulks of liquid is Hydrodynamic Cavitation (HDC).

The hydrodynamic cavitation is the most suitable non chemical method for removal of TDS and Hardness from the industrial circulating water[1].

The bubbles form and collapse continuously resulting in creating localized points of extreme high temperature and pressure. The collapsing bubbles contract to a minute fraction at which the gas within the bubble dissipates into the surrounding liquid. This releases a huge amount of energy in the form of an acoustic shock wave and as visible light.

The energy thus released due to collapsing of bubbles results in formation of precipitate of calcium and magnesium which are the key affecting elements in the TDS and Hardness of water. The energy released due to the low pressure formation in the chamber also removes a large scale of micro-organisms.

MECHANISM OF TANGENTIAL FLOW SWIRLING NOZZLE

The water from the colleting tank is pumped at pressure into the chamber through two oppositely faced convergent nozzles fitted to the chamber. The water enters the chamber tangentially through opposite sides of the nozzle [3-4].

The water entering the chamber expands at higher velocities causing a low pressure area in the middle of the chamber. The low pressure thus created results in continuous formation and collapsing of bubbles. The high energy thus released through the process causes the calcium carbonate and magnesium carbonate to form a precipitate in the water.

The precipitate thus formed is filtered separately through a filtration tank and the treated water is added with makeup water for further circulation.

Design Parameters of Nozzle

The prime purpose of the nozzle is to achieve higher exit velocities. The design characteristics of the nozzle determines the fluid acceleration rate. The nozzle performance is determined by the minimum energy losses at various operating conditions. The convergent nozzle designed and used here is typically designed for serving the purpose of creating an Hydro Dynamic Cavitation effect[6-8].

Table1: Nozzle Parameters

Nozzle Outer Diameter	75mm
Water Inlet Diameter	35mm
Length of Nozzle	50mm
Nozzle Exit Diameters	16,14,12mm
Cover Plate Diameter	75mm
Water entry from Tangential hole of nozzle diameter	8mm
Air entry from cover plate nozzle	6mm

Design Parameters of Filtering Tank & Cavitation Chamber

Table 2

Length	130cm
Width	130cm
Height	130cm
Cavitation chamber	200, 300, 400mm

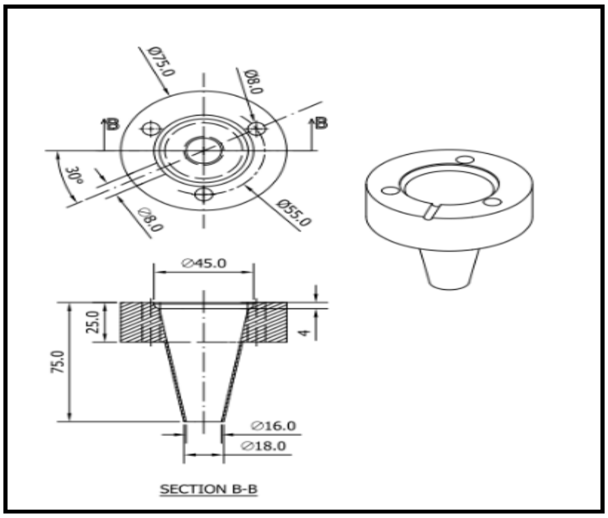

Figure 1: Layout of Tangential Flow Nozzle

Model of a Nozzle

Initially in experimental work, a tangential opposite holes of a nozzle is designed.

Nozzle designs are shown in the figure.

Figure 2: Nozzles with Top Plate

Assembly of HDC with Filtration Tank

The equipment consist of two nozzles fitted in opposite directions in a closed chamber. The water is allowed to flow through these nozzles tangentially[9-10].

The inlet flow of water is monitored using flow meters and is recorded. The treated water exits from the drain of the cavitation chamber to the filtration tank.

An air compressor of 8 bar capacity is attached to the nozzles and the air flow is regulated through valves.

The assembly layout diagram is shown in figure 4

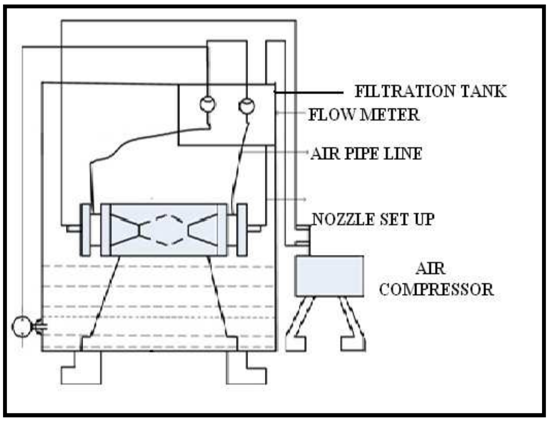

Figure 3: Assembly of HDF with Filtration Tank

EXPERIMENTS

Ground water sample is collected, and water analysis has done as per IS: 10500:2012. So, the results obtained are

Table 3: Ground Water Sample Results

Sl. No	Characteristic	Test Method	Results	Acceptable Limit
1	Total Dissolved Salts, mg/l	IS:3025(pt-16)	946	< 500
2	Total Hardness as $caco_{3,}$ mg/l	IS:3025(pt-21)	528	< 200
3	Calcium as ca, mg/l	IS:3025(pt-40)	121.6	< 75
4	Magnesium as Mg, mg/l	IS:3025(pt-46)	53.8	< 30
5	pH value	IS:3025(pt-11)	7.10	6.50-8.50
6	Electrical Conductivity, µs/ cm	APHA	1412	N. A
7	Turbidity, NTU	IS: 3025 (pt-10)	6.9	< 1

Experiments

Experiment Conducted Water at Pressure 1 bar, Cavitation Chamber of Length 300mm

At Air Pressure 1 bar the cavitation chamber of length 300mm, water Circulating 30 min through a nozzle of 16 mm exit diameter.

Now collect water sample after 30, 60, 90, 120, 150 minutes, Calcium, Magnesium, TDS, hardness, Electrical Conductivity and Turbidity results obtained for water analysis as mentioned in a table below.

Table 4: Water Analysis Results at a Pressure 1 Bar

S. No	Characteristic	RW Characteristics	Settling Time 30 min	Settling Time 60 min	Settling Time 90 min	Settling Time 120 min	Settling Time 150 min
1	Calcium Ca, mg/l	121.6	102.4	99.2	96.8	92.8	101.6
2	Magnesium Mg, mg/l	53.8	44.2	42.2	41.8	40.3	42.7
3	TDS, mg/l	946	786	784	770	756	790
4	Hardness, mg/l	528	440	424	416	400	432
5	Electric conductivity µs/cm	1412	1174	1172	1150	1130	1180
6	Turbidity NTU	6.9	3	2.9	2.7	2.6	2.6

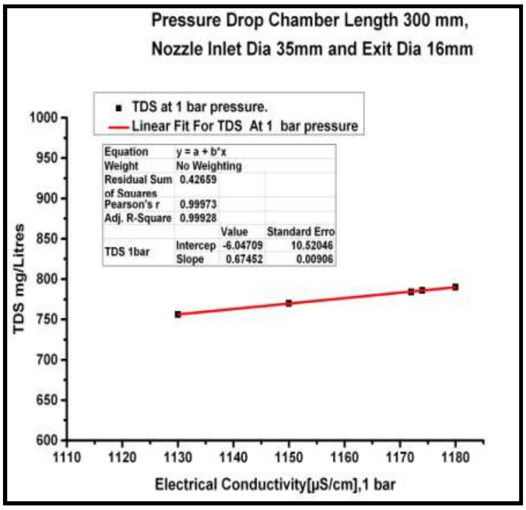

Figure 4: TDS Vs EC at 1 Bar Pressure

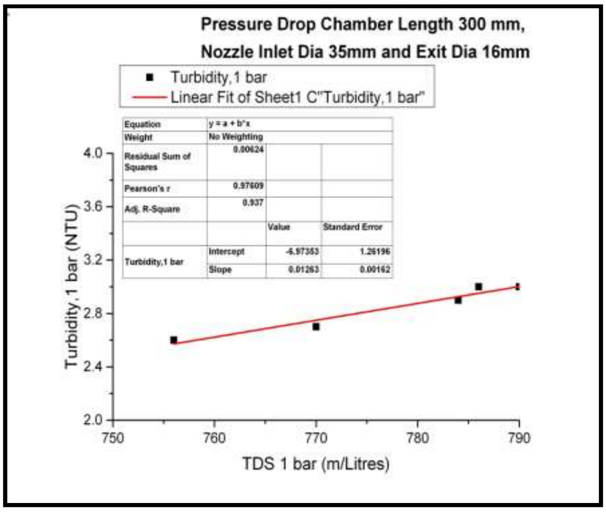

Figure 5: TDS Vs Turbidity at 1 Bar Pressure

Experiment Conducted Water at Pressure 1.5 bar, Cavitation Chamber of Length 300mm

At Air Pressure 1.5 bar the cavitation chamber of length 300mm, water Circulating 30 min through a nozzle of 16 mm exit diameter.

Now collect water sample after 30, 60, 90, 120, 150 minutes, Calcium, Magnesium, TDS, hardness, Electrical Conductivity and Turbidity results obtained for water analysis as mentioned in a table below.

Table 5: Water Analysis Results at a Pressure 1.5 Bar

S. No	Characteristics	RW Characteristics	Settling Time 30 min	Settling Time 60 min	Settling Time 90 min	Settling Time 120 min	Settling Time 150 min
1	Calcium as ca, mg/l	121	102.4	98.4	97.6	93.6	96
2	Magnesium as Mg, mg/l	53.8	44.2	42.7	42.2	39.8	40.3
3	TDS, mg/l	946	782	778	776	748	733
4	Hardness, mg/l	528	440	424	420	400	408
5	EC µs/cm	1412	1136	1164	1160	1118	1168
6	Turbidity NTU	6.9	2.8	2.8	2.8	3	2.5

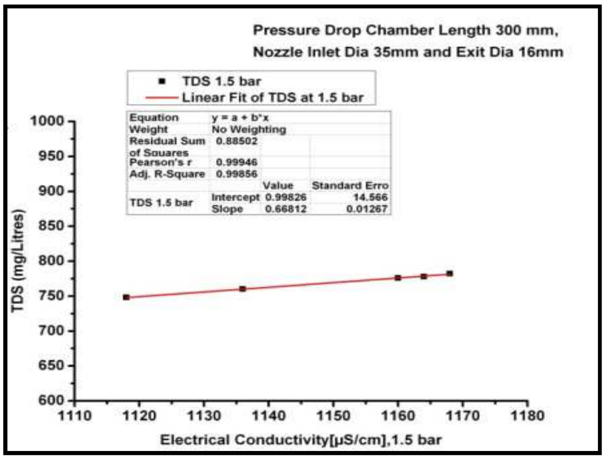

Figure 6: TDS Vs EC at 1.5 Bar Pressure

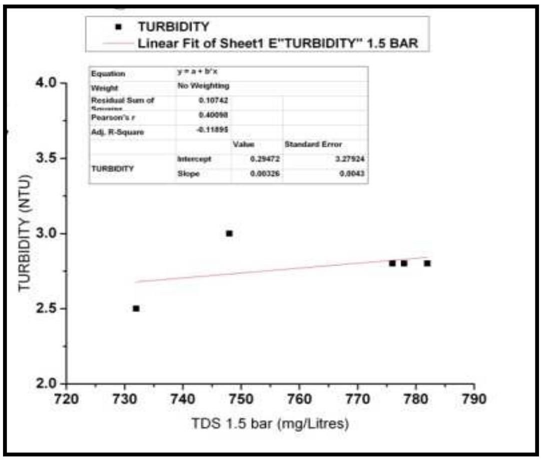

Figure 7: TDS Vs Turbidity at 1.5 Bar Pressure

Experiment Conducted Water at Pressure 2 Bar, Cavitation Chamber of Length 300mm

At an inlet air Pressure 2 bar in the cavitation chamber of length 300 mm, water Circulating 30 min through a nozzle of 16 mm exit diameter.

Water sample is collected after 30, 60, 90, 120, 150 minutes, TDS, hardness, Electrical Conductivity and turbidity results obtained from water analysis are as mentioned in a table below.

Table 6: Water Analysis Results at a Pressure 2 Bar

S. No	Characteristic	Raw Water Characteristic	Settling Time 30 min	Settling Time 60 min	Settling Time 90 (min)	Settling Time 120 min	Settling Time 150 min
1	Calcium as ca, mg/l	121	100.8	97.6	96	96	93.6
2	Magnesium as Mg, mg/l	53.8	43.2	41.3	41.3	40.3	39.8
3	TDS, mg/l	946	744	734	722	754	740
4	Hardness, mg/l	528	432	416	412	408	400
5	EC µs/cm	1412	1112	1098	1112	1126	1110
6	Turbidity NTU	6.9	2.7	2.8	2.6	2.8	2.7

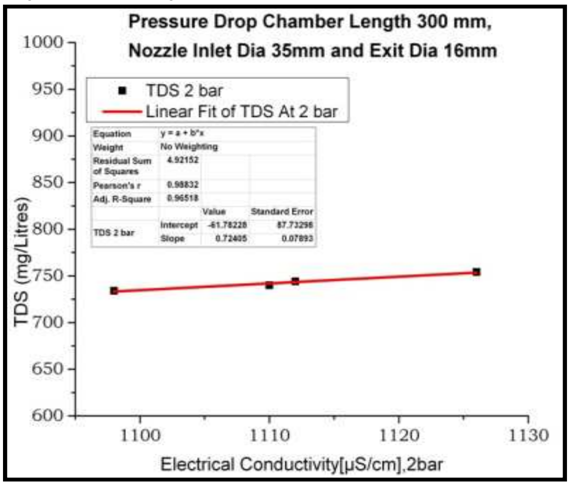

Figure 8: TDS Vs EC at 2 Bar Pressure

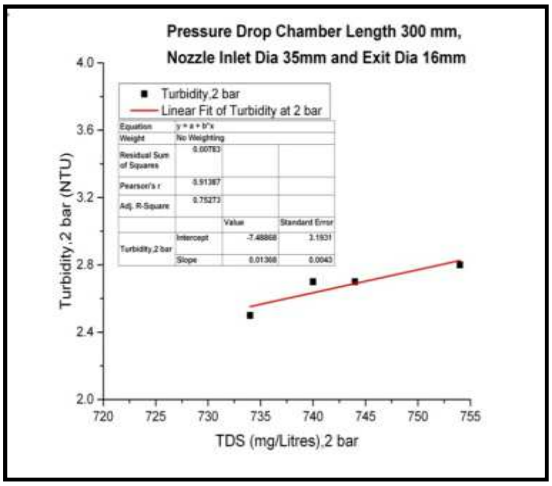

Figure 9: TDS Vs Turbidity at 2 Bar Pressure

RESULTS & DISCUSSIONS

The study of the impact of TDS on the Electrical Conductivity and turbidity by treating water through a hydrodynamic cavitation method in a closed chamber length of 300 mm and nozzle inlet diameter of 35 mm and exit diameter of 16 mm for various inlet air pressures is concluded below.

- At an inlet air pressure of 1 bar and at the increase in the settling time for 30 min each, the TDS decreases from 946 mg/L to 756 mg/L at 120 min and then increased to 790mg/L at a settling time of 150 min. For this change in TDS, the electrical Conductivity decreases from 1412 µs/cm to 1130 µs/cm at a settling time of 120 min and then increases to 1182 µs/cm at a settling time of 150 min. The turbidity also decreased from 6.9 NTU to 2.6 NTU at a settling time of 150 min.
- At an inlet air pressure of 1.5 bar and increasing settling time of 30 min each, the TDS decreased from 946 mg/L to 733 mg/L at a settling time of 150 min which resulted in subsequent reduction in Electrical conductivity from 1412 µs/cm to 1168 µs/cm and turbidity reduction from 6.9 NTU to 2.5 NTU.
- At an inlet air pressure of 2 bar and increasing settling time of 30 min each, the TDS decreased from 946 mg/l to 740 mg/L at a settling time of 150 min which resulted in reduction of Electrical conductivity from 1412 µs/cm to 1110 µs/cm and turbidity reduced from 6.9 NTU to 2.7 NTU.

CONCLUSIONS

This indicates that the relationship between the TDS and the Electrical Conductivity (EC) is not always linear as observed with the readings. The correlativity depends on the contents of the water and the presence of mineral salts. The correlativity between the TDS and the Turbidity is also not always linear as the presence of few minerals impact the Turbidity of water regardless of the TDS.

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